Permanent Ridge-till Sorghum with Furrow Irrigation

R. R. Allen, J. T. Musick

Abstract. *Planting of row crops on permanent ridges was developed primarily in the cornbelt, but is being adapted for graded furrow irrigation. This study was conducted during 1992-1995 on the Southern High Plains at Bushland, Texas, to determine the effect of permanent ridge-furrows on between-crop soil water storage, irrigation infiltration, evapotranspiration (ET), grain yield, and water use efficiency (WUE) with grain sorghum; and to determine effect of precision cultivation with reduced herbicide application for weed control. Treatments were ridge-till (RT), conventionally tilled bed planting (BED), and flat planting (FLAT) with furrows opened during cultivation on a 550 m (1800 ft) furrow run. Seedling emergence and heading were one to two days earlier for RT in two of three years. Mean grain yields were highest for RT at 7.91 Mg/ha (7400 lb/ac) compared with 7.17 and 7.54 Mg/ha (6380 and 6710 lb/ac) for BED and FLAT treatments, respectively.*

The WUE averaged 1.26, 1.08, and 1.19 kg/m³ (285, 244, and 269 lb/ac-in.) for RT, BED, and FLAT treatments, respectively. The WUE for RT was significantly higher than for the BED treatment. The RT cultural operation and planting costs were about \$50.20/ha (\$20.30/ac) lower than for BED planting while FLAT planting treatment costs were \$12.30/ha (5.00/ac) lower than BED planting. RT and FLAT planting were less dependent on rainfall to provide a moist seed zone than was BED planting. Precision cultivation successfully controlled 90 to 95% of weeds compared with 95 to 98% control with atrazine herbicide. **Keywords.** *Tillage, Ridge-till, Furrow irrigation,*

Methods of primary tillage between annual crops of irrigated corn or sorghum on the Southern High Plains commonly include disking and chiseling with occasional ripping or mold plowing for deeper soil loosening. With furrow irrigation, row crops are usually planted on elevated beds (ridges) separated by irrigation furrows. An alternate practice is to plant on a flat surface with furrowing performed after crop emergence during the first cultivation. In either case, crop residue is mostly mixed into the soil by planting time and the cultural operations result in a relatively dry seedbed. As a result, a preplant or an emergence irrigation may be needed for germination.

An alternative method of planting row crops on permanent ridges (ridge-till) was developed primarily in the cornbelt. The evolvement of ridge-till started after Buchele and associates (1955) introduced contour planting of corn on clean-tilled listed ridges in Iowa to reduce water erosion. Later, research in Nebraska by Wittmuss et al. (1971) indicated that successful planting could be accomplished on old crop ridges without primary tillage. They developed a till-planter that removed residue and some soil from the old ridges providing a clean seed row strip of relatively warm, moist, and mellow soil. Heavy duty cultivators were needed to operate through interrow residue, control weeds, and rebuild plant row ridges. Present refined ridge-till procedures may include a band application of herbicide to the cleared seed row strip for control of early weeds, but the basic technique still uses primarily sweep, finger, or disc clearing devices mounted on or operated ahead of row planters.

The cultural advantages of ridge-till were rather easily adapted by Norton and Eisenhauer (1991) to furrow irrigation since cultivation between crop rows to rebuild ridges established suitable water conveyance furrows. They found that ridge-till furrows had slower furrow water advance rates and higher irrigation infiltration, compared with clean tillage and reformed beds/ridges in tests on a Hastings silt loam in South Central Nebraska. Schlegel and Dhuyvetter (1995) found that ridge-till culture increased soil water storage available at planting by about 25 mm (1 in.) because of some snow trapping and reduced evaporation under residues on a Ulysses silt loam in Western Kansas. Smith (1992) reported a \$75/ha (\$30/ac) reduction in production costs with ridge tillage without reducing irrigated corn yield on a nearby Ulysses soil. Unger (1994) found that ridge tillage increased soil water available at planting by 31 mm (1.2 in.). Precipitation was 14 mm (0.6 in.) above average during the between-crop period in the six-year study between 1986 and 1992 at Bushland, Texas. Unger reported seasonal soil water depletion to be 66 mm (2.6 in.) with ridge tillage compared with 51 mm (2 in.) for conventional tillage.

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The objectives of this study were to determine the effect of permanent cultivated ridge/furrows on between-crop soil water storage, irrigation infiltration, ET, grain yield, and WUE for grain sorghum production; and to determine the effect of precision cultivation with permanent crop ridges versus a triazine herbicide for seasonal weed control.

Procedure

The study was conducted during the 1992 to 1995 crop years at the USDA Conservation and Production Research Laboratory, Bushland, Texas. The soil, a fine textured and slowly permeable Pullman clay loam (*Torrertic Paleustoll*), was described by Unger and Pringle (1981). This soil has a plant available water holding capacity (ASW) of 180 mm (7.2 in.) to a 1.2 m (4 ft) rooting depth for sorghum.

Treatments were designated as:

RT– Permanent ridges with herbicide subplots.

BED– Conventional chisel, rotary till, rebed.

FLAT–Chisel, rotary till, flat plant, open water furrows by cultivation.

The experimental design was a randomized block, split plot with four replications. Main tillage treatment plots for continuous irrigated grain sorghum were 4.6 m (15 ft) wide × 550 m (1800 ft) long and contained six 0.75 m (30 in.) spaced ridge-furrows on a 0.35% grade. The upper 360 m (1200 ft) of RT treatment strips were divided into four 90 m (300 ft) length subplots alternately having herbicide and no herbicide treatments.

The experimental site was previously cropped to grain sorghum after fallow in the summer of 1992 and had relatively low weed density. Stalks were shredded and a disk-bedder was used during the winter on RT plots to move soil to the stalk row and form the permanent ridges for the three-year study. Anhydrous ammonia was knifed into row middles at 180 kg/ha (160 lb/ac) N. The BED and FLAT clean tillage plots were chiseled to the 150 mm (6 in.) depth on 0.3 m (1 ft) centers followed by rotary tillage for residue/soil mixing. Bed-furrows were formed with a disk-bedder on the BED plots.

About two weeks before planting (table 1), Roundup™ (glyphosate) was applied at 1.75 kg/ha (25 oz/ac) total material to control weeds and volunteer sorghum on RT plots. A tank mix of propazine at 1.7 kg/ha (1.5 lb/ac) and Dual™ (metolachlor) at 2.25 kg/ha (2 lb/ac) AI was applied preplant on BED and FLAT plots for broadleaf and grass control. A six-row planter (IH 800 Cyclo) with staggered double-disk seed slot openers was used. ACRA-Plant "trash whippers", with staggered and notched residue/soil clearing disks forming a "V", were mounted in front of seed openers to remove 25 to 40 mm (1 to 1.6 in.) of soil from the ridge on RT plots. Atrazine™ was applied post-emergent at 1.7 kg/ha (1.5 lb/ac) AI as the herbicide treatment on RT subplots. After plants were at the 5-8 leaf stage, a ridge-till residue cultivator (Buffalo 6300) was used with an electronic plant-row sensing guidance hitch (Buffalo Scout) to cultivate and reform water furrows while moving soil to the plant row, reforming the ridge. The cultivator was also used to form irrigation furrows on the FLAT plots and to reshape furrows on the BED plots.

Table 1. Planting, irrigation, and harvest dates

Year	Plant Date	Irrigation Dates	Harvest
1993	2 June	8 June*, 12 July†, 17 Aug.	28 Oct.
1994	31 May	28 June, 1 Aug., 22 Aug.	20 Oct.
1995	8 June	13 July, 27 July, 17 Aug., 31 Aug.	30 Oct.

* First (emergence) application for BED treatment.

† First application for RT and FLAT treatments.

Irrigation was applied through gated pipe and measured with a propeller meter (table 1). Individual furrow inflow rates were measured and adjusted by use of a volumetric container and stopwatch. Tailwater was measured through individually calibrated, portable H-flumes with float-operated, electric-clock-driven, FW-1 type water-stage recorders. The flume for each plot received runoff from two wheel-track and two non-track furrows. Furrow inflow rates were set at 0.75 L/s (12 gpm) for the first irrigation after tillage to complete the advance phase in 16 to 20 h. About 4 h of additional time was allowed for furrow runoff during the infiltration phase. This procedure provides an infiltration opportunity time on the upper 2/3 to 3/4 of the furrow length that is usually adequate to rewet this soil to the 1.2 m (4 ft) sorghum rooting depth (Allen and Musick, 1995). The lower 1/4 to 1/3 may not be fully wetted (moderate deficit) in order to avoid excessive runoff on this slowly permeable soil. After furrow surface consolidation from the first irrigation, inflow rates were set at 0.62 L/s (10 gpm) for the remainder of the season. Soil water content was measured gravimetrically by core samples in 0.3 m (1 ft) increments to 1.8 m (6 ft). Four core samples were obtained before planting, emergence, and at harvest. Evapotranspiration (ET) was determined by the water balance method using beginning and ending soil profile water contents (assuming negligible deep percolation), net irrigation, and precipitation less runoff. Grain yields were determined by harvesting 90 m (300 ft) four-row subplots, and adjusting to 13.5% moisture (wb) (table 1). Water use efficiency (WUE) was determined as the ratio of grain yield to ET. Subplot treatment means were tested for significance at the $P < 0.05$ level using Statgraphics (Manugistics, 1992) for analysis of variance.

Results and Discussion

Cultural Operations

For discussion, crop years 1993, 1994, and 1995 are referred to as years 1, 2, and 3. The RT plots required no cultural operations during winter and early spring, except in year 3 when animal burrowing required a furrow clearing operation with the cultivator to remove random mounds in furrows. The preplant application of glyphosate on RT plots was successful in controlling kochia and volunteer sorghum, which confirmed previous results with minimum-till, graded furrow irrigated sorghum research (Allen, 1985). The RT planting was accomplished with the assistance of guide cones to hold the planter openers on ridge centers. Only 25 to 40 mm (1 to 1.6 in.) of soil and old root crowns were removed from the ridge with the trash whippers, which left a firm moist seedbed for planting. With the BED treatment in year 1, beds were dry to planting depth from spring tillage operations and required an emergence irrigation to germinate seed. The RT and FLAT plots had adequate soil water content for seedling emergence. In years 2 and 3, sorghum was established on all tillage treatment plots without a preplant or emergence irrigation.

Table 2. Cultural operation costs

	Tillage System		
Operation	RT ($/ha)	BED ($/ha)	FLAT ($/ha)
Shred stalks	14.80*	14.80	14.80
Apply NH³	14.80	14.80	14.80
Disk (2)		24.70	24.70
Chisel		13.60	13.60
Bed		12.30	
Herbicide	29.60	32.10	32.10
Plant	17.70	14.80	14.80
Cult.	17.70	17.70	17.70
Total	94.60	144.80	132.50

* Source: Kansas Department of Agriculture (1995).

Cultivation accomplished both the opening of a water furrow and the re-establishment of a ridge at the plant row. The electronic guidance hitch maintained cultivator alignment and permitted positioning of borrowing disks close to plants to control small weeds and volunteer sorghum.

Subplot treatments with atrazine had minor affects on weed and annual grass control. In year 1, atrazine had about 95% control and cultivation-only produced 90% control. In year 2, there was about 98% pigweed control with atrazine and 95 to 97% control with cultivation only. There were a few random clusters of crabgrass not related to herbicide treatment or tillage. In year 3, there was no apparent additional control from atrazine as compared to cultivation only, and there were a few more random clusters of crabgrass. It appeared that annual grass pressure may require rotating to new clean field areas after three to four years of continuous summer row cropping, regardless of tillage method.

Costs of cultural operations through planting and cultivating are presented in table 2. The RT costs were $50.20/ha ($20.32/ac) less than conventional tillage and bedding costs and $37.90/ha ($15.34/ac) less than the FLAT treatment. These operational cost savings with RT are comparable to those reported by Smith (1992) where he did not have a glyphosate expense before planting RT corn, thus increasing savings to about $74.00/ha ($30.00/ac).

Cone index (soil strength) values in furrows are presented in figure 1 as an indicator of increased soil density from wheel traffic compaction. Soil strength peaked sharply at about 75 mm (3 in.) deep in wheel track furrows; whereas, strength increased gradually to the 150 to 200 mm (6 to 8 in.) depth in no-traffic furrows. All strengths were about the same below 150 mm (6 in.) which was below tillage depth and is at the top of the dense B horizon of a Pullman soil. These values were measured in year 3 for the RT and BED treatment plots on 7 August 1995, after two seasonal irrigations when the furrow surface was consolidated and relatively smooth. The RT wheel track furrows were slightly more dense than the conventionally tilled and bedded wheel track furrows. Soil strength for the FLAT treatment was similar to the BED treatment and is not included in the graph in order to improve clarity.

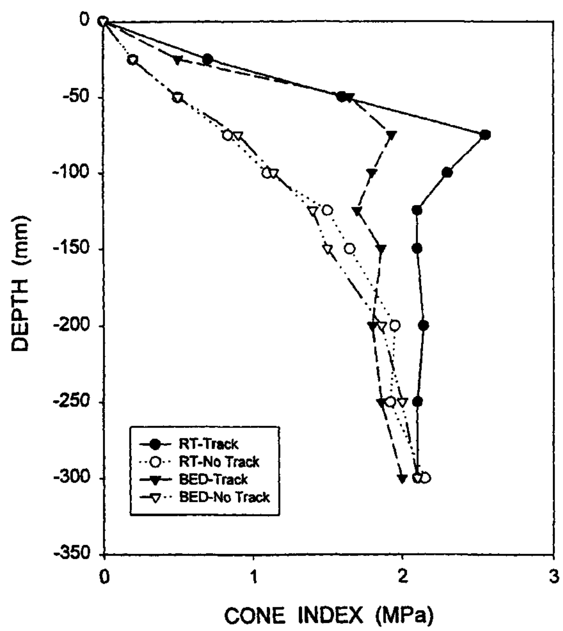

Figure 1–Cone index (soil strength) vs depth in wheel traffic and no-traffic furrows on 9 August 1995, for ridge (RT) and bed (BED) treatments (1 Mpa = 145 psi, 25 mm - 1 in.).

Water Management

Preseason (November through May) precipitation (table 3) was near the average at 174 mm (6.85 in.) during crop years 1 and 2. In year 3, preseason precipitation through April was only 51 mm (2 in.) or 48% of average and plots of all treatments were too dry for planting until 119 mm (4.7 in.) of May rainfall occurred. This May rainfall was 74% above average and provided adequate soil water for the early June planting (fig. 2). Plant available soil water (ASW) content to the 1.8 m (6 ft) depth at emergence is presented in table 3 for the three crop years. The ASW was lowest at planting in year 2 but was adequate for germination. Growing season precipitation was below average each year (table 3) and especially in year 3 when only 191 mm (7.5 in.) or 63% of average was received. Maintaining the surface flat over winter before planting provided about the same soil profile water storage and nearly as moist a seed zone as did RT. Both RT and

Table 3. Treatment effects on soil water content, water applied, ET, grain yield, and WUE

		Available Soil Water to 1.8 m			Rainfall				
		Planting (mm)	Harvest (mm)	Net Irrig. (mm)	Preseason (Nov-May) (mm)	Growing Season (Jun-Oct) (mm)	Grain ET (mm)	Yield (Mg/ha)	WUE (kg/m³)
1993	RT	178	69	221	174	274	604	7.82	1.29
	BED	234*	60	242			690	7.37	1.07
	FLAT	171	69	208			584	7.50	1.28
	LSD (0.05)						(32)	(0.28)	(0.12)
1994	RT	96	64	410	170	273	715	8.77	1.23
	BED	89	74	400			688	7.42	1.08
	FLAT	108	85	402			698	7.73	1.11
	LSD (0.05)						(NS)	(0.30)	(0.10)
1995	RT	126	152	396	199	191	561	7.13	1.27
	BED	140	123	399			607	6.71	1.11
	FLAT	140	112	398			617	7.40	1.20
	LSD (0.05)						(41)	(0.31)	(0.10)
MEANS	RT	133	95	342	181	246	626	7.91	1.26
	BED	154	86	347			661	7.17	1.08
	FLAT	140	89	336			633	7.54	1.19
	LSD (0.05)						(NS)	(0.47)	(0.13)
56 Yr Avg. Precip.					174	302			

* Includes emergence irrigation.
25.4 mm = 1 in., 1 Mg/ha = 890 lb/ac, 1 kg/m³ = 226 lb/ac-in.

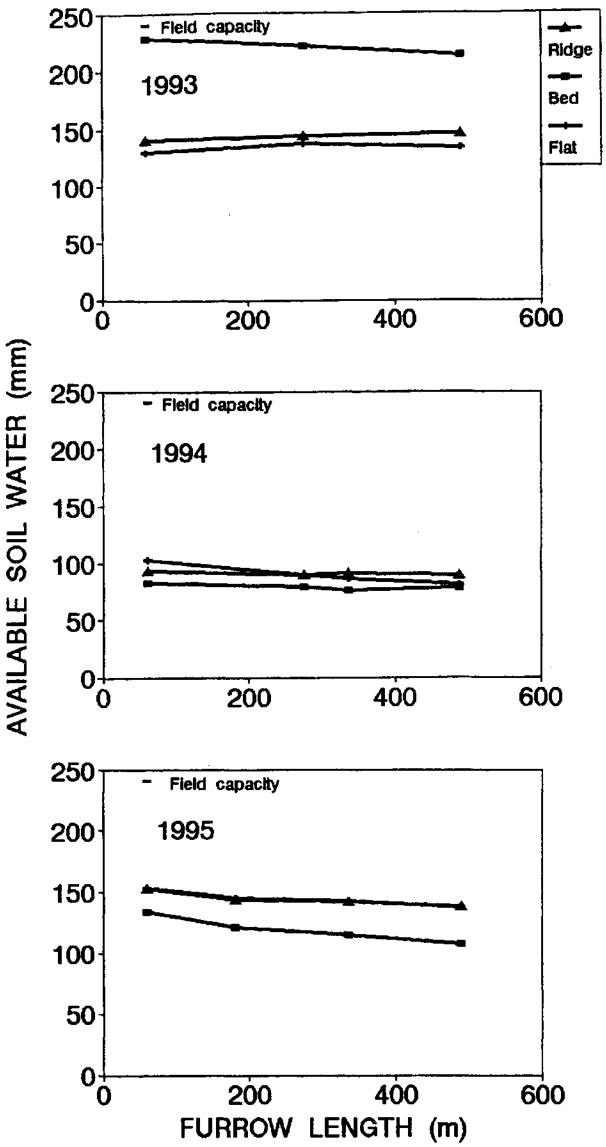

Figure 2–Plant available soil water to the 1.8 m (6 ft) depth vs furrow length at plant emergence (1 m = 3.28 ft, 25 mm = 1 in.).

FLAT planting lessened the need for a preplant or emergence irrigation that may be required for conventionally tilled and reformed beds that may be dry at seeding depth because of recent tillage and bed forming. Round top beds tend to shed rainfall, which can limit wetting to the seeding depth (Allen and Musick, 1990).

Profile ASW at planting is presented in figure 2. In year 1, an emergence irrigation was necessary to wet the BED treatment plots after tillage and bed forming. In this study, we did not experience an average 25+ mm (1 in.) increase in over-winter soil water storage in the soil profile at planting with RT compared with other treatments as did Schlegel and Dhuyvetter (1995) at Tribune, Kansas, and Unger (1994) at Bushland, Texas. We attribute this to the relatively dry winters during the study with very little snow.

Net irrigation application, water use (ET), grain yield, and water use efficiency (WUE) are presented in table 3. The emergence irrigation for the BED treatment in year 1 significantly increased ET and lowered WUE. The three-year average ET for RT and FLAT treatments were nearly equal at 627 and 633 mm (24.7 and 24.9 in.), respectively. WUE was significantly higher for RT compared with the BED treatment. Average WUE for FLAT planting was nearly as high as RT, 1.19 kg/m^3 versus 1.26 kg/m^3 (269 vs 285 lb/ac-in.), respectively.

Table 4. Irrigation water advance times for 550 m (1800 ft) length traffic and no-traffic furrows

Treatment	Traffic (h)	No Traffic (h)	Traffic (h)	No Traffic (h)	Traffic (h)	No Traffic (h)
1994	6/28*		8/1		8/22	
RT	14.2	18.0	11.5	13.5	10.5	11.7
BED	14.0	18.3	12.0	14.1	9.9	11
FLAT	13.0	17.1	13.0	15.0	10.2	11.5
LSD (0.05)	(2.05)		(1.95)		(NS)	
1995	7/13		7/27		8/31†	
RT	14.5	17.5	11.0	13.0	14.0	15.5
BED	14.7	17.3	11.2	13.0	13.8	15.7
FLAT	15.2	17.9	11.6	13.4	14.3	15.9
LSD (0.05)	(2.17)		(1.80)		(NS)	

* Irrigation date.
† Data for 8/14/95 irrigation not presented, 25 mm (1.0 in.) rainfall received during application.

Furrow water advance times are presented in table 4 for years 2 and 3 when all tillage treatments were irrigated on each irrigation date. There were no significant differences in advance rate between tillage treatments, apparently because the furrow cultivation and ridging operation before the first seasonal irrigation left a similar furrow shape and roughness for each treatment. Water advanced significantly faster in wheel traffic furrows than in no-traffic furrows during the first two irrigations each year because of the traffic compaction. The decreasing difference in advance times between traffic and no-traffic furrows after the first irrigation in this study was the result of furrow surface consolidation. Allen and Musick (1997) reported irrigation infiltration in wheel track furrows on the Pullman soil at Bushland to be reduced from about 15 to 40% depending on tractor mass and the cumulative effect of repeated traffic in the same furrows.

Plant Growth and Grain Yield

In year 1, sorghum on RT plots emerged and headed two to three days earlier than on other treatment plots. This is attributed to the more rapid germination associated with warmer soil, higher moisture, and a firmer condition of the ridge. The favorable ridge soil condition enhanced plant development and rooting during the early vegetative growth stage of about 30 days. The early season plant growth and rooting development differences were based on visual observations. No above ground biomass or root measurements were made. In year 2, sorghum on RT plots emerged and headed one to two days earlier than on conventional tillage plots. This early plant development and rooting apparently contributed to a higher grain yield for RT during years 1 and 2. In year 3 after a very dry winter; plant residue remained largely undecomposed leaving a loose fluffy seedbed. This condition was partially the result of a furrow clearing operation to remove animal burrowing mounds. In year 3, plant growth was similar on all treatment plots and flat planting resulted in the highest yields, although not significantly higher than RT. The

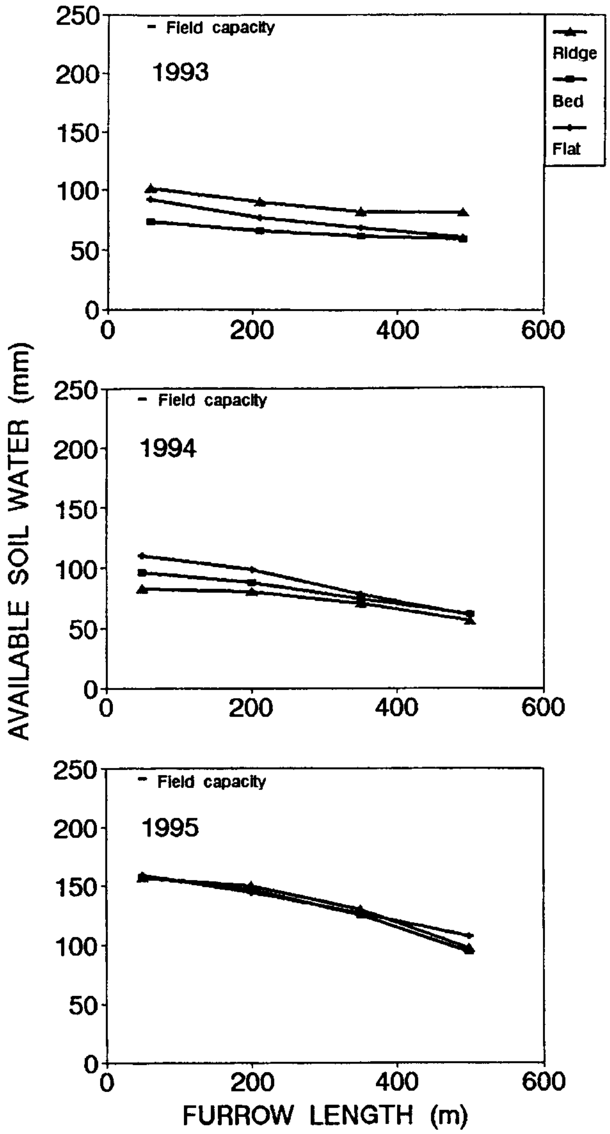

Figure 3–Plant available soil water to the 1.8 m (6 ft) depth vs furrow length at harvest (1 m = 3.28 ft, 25 mm = 1 in.).

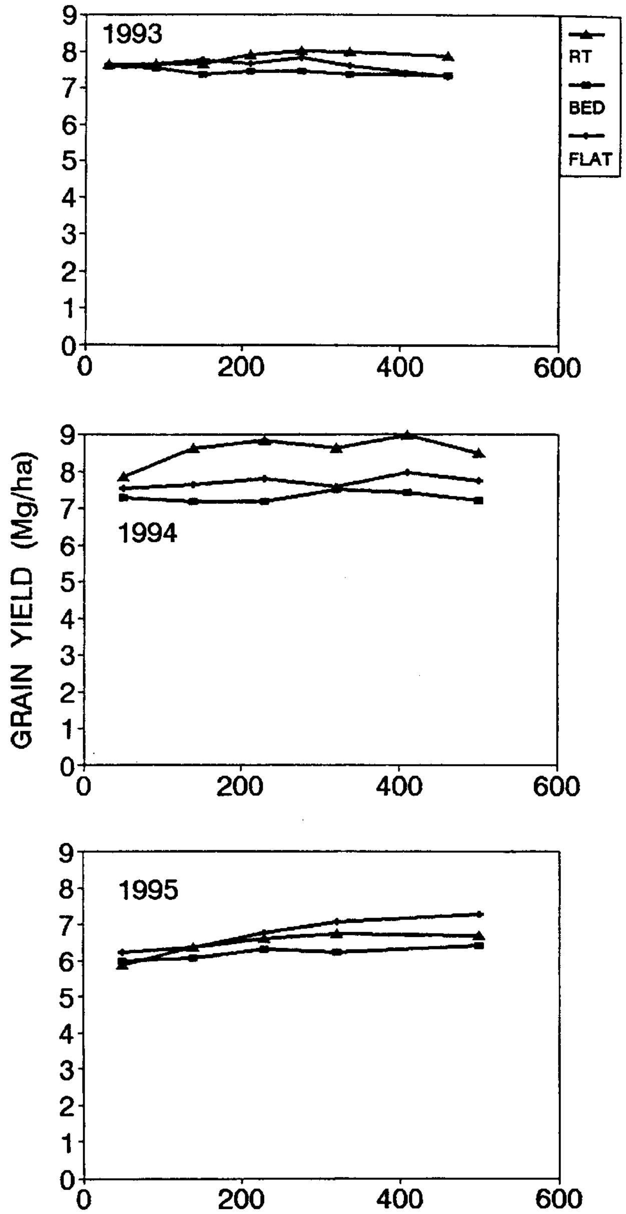

Figure 4–Grain yield vs furrow length (1 m = 3.28 ft, 25 mm = 1 in.).

three-year average grain yield and WUE were highest for RT. Grain yield and WUE averaged significantly less for the conventional BED treatment plots compared with RT.

In year 1, some visual plant stress occurred on the lower 1/3 of the field during late grain filling with the BED and FLAT treatments. As a result, some lodging occurred with these conventional tillage treatments on the lower end, but none occurred with RT. RT resulted in slightly higher ASW [about 20 mm (0.8 in.)] at harvest in year 1 (fig. 3). This higher late season ASW and reduced lodging with RT contributed to about 0.6 Mg/ha (500 lb/ac) higher yield on the lower 1/3 of the field (fig. 4), compared with conventional tillage. In year 2, ASW on the lower 1/3 was down to about 60 mm (2.4 in.), but no stress related lodging occurred. In years 2 and 3, ASW declined along the furrow length by harvest as expected with moderate deficit irrigation management on the lower 1/3; however, grain yield (fig. 4) was relatively uniform throughout the field length indicating that late season soil water contents were not yield limiting.

Summary and Conclusions

1. The RT culture resulted in slightly earlier seedling emergence and plant development with a higher average grain yield and WUE compared with conventional tillage and BED or FLAT planting.
2. Maintaining the surface flat over winter before planting provided about the same soil profile water storage and nearly as moist a seed zone as did RT, thus RT and FLAT planting were less dependent on timely rainfall for seedling germination and emergence than was conventional tillage and BED planting.
3. Precision furrow cultivation was nearly as effective as conventional herbicide for growing season weed control, thus reducing herbicide application needs.
4. Furrow water advance times were similar for all tillage treatments, apparently because the furrow cultivation/ridging operation before the first

growing season irrigation left a similar furrow shape and roughness for each treatment. Wheel traffic furrows advanced significantly faster than did no-traffic furrows during the first two irrigations each year.

5. RT operational costs were reduced by \$50.20/ha (\$20.32/ac) compared with conventional tillage and BED planting.

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